INFRARED DETECTION OF PIPELINE LEAKS

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RESEARCH AND DEVELOPMENT SUBCOMMITTEE

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1.0 INTRODUCTION

Infrared radiation detection systems have received increasing attention in recent years. Mounted under a helicopter or fixed wing aircraft, the systems detect infrared radiation from all objects warmer than absolute zero (-272oC) and display the objects through an on-board video unit.

As only a slight differential in temperature is required to detect an object from its surroundings, the systems have been used successfully by the military and law enforcement agencies. The Alberta Forest Service regularly uses infrared detection as an effective method to detect forest fire hot spots, to inspect winter burning projects, to map ongoing fires and to evaluate fire retardant systems.

Infrared imagery has also been promoted as a method to detect crude oil and produced water pipeline leaks. Despite the use of flow monitoring equipment within a pipeline system and surface or aerial patrols for buried pipelines, leaks still occur. In remote or inaccessible areas, leaks can go unnoticed until they reach a significant size. The CPA PROSCARAC Research and Development Sub-Committee commissioned this demonstration project to explore the effectiveness of infrared leak detection systems and the differences between two available products. The objective was to assess the suitability of the technique to detect oil or produced water spills.

2.0 THE INFRARED SYSTEMS

Two systems were made available for the demonstration. The FLIR, "Forward-Looking InfraRed", supplied by Turbowest Helicopters Ltd. of Calgary and the AGA supplied by Aerial Recon Surveys of Whitecourt. A graphical representation of how the units function is shown in Figure 1.

Although the FLIR system is referred to as "state of the art", both units are able to detect temperature variations of 0.2oC. In addition to providing an infrared image, the AGA system also records the corresponding actual video image on a split image screen.

Although infrared systems have proven to be scientifically capable of detecting heat variations, the success of any infrared program is dependant on the technical qualifications and experience of the observer or "thermographer". Besides being able to detect the meaning and degree of heat differentials on the video monitor, the thermographer must be completely fluent with the operation of the camera controls, the video recording units, aerial photography principles, and with the AGA system: the operation of the split screen video format.

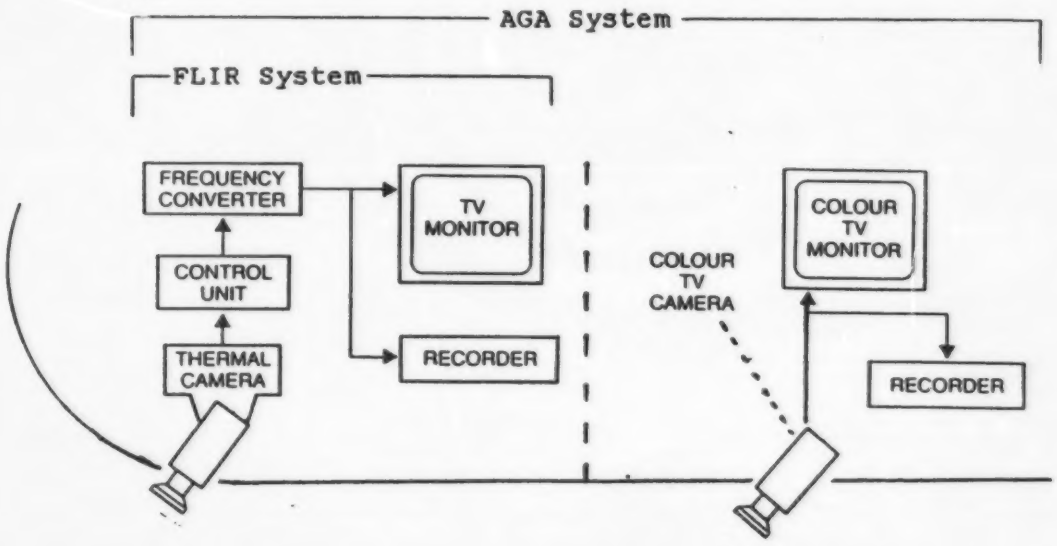

Figure 1: Graphical representation of an infrared imagery system.

Photo 1: FLIR infrared camera mounted on Turbowest Bell 206L Long Ranger.

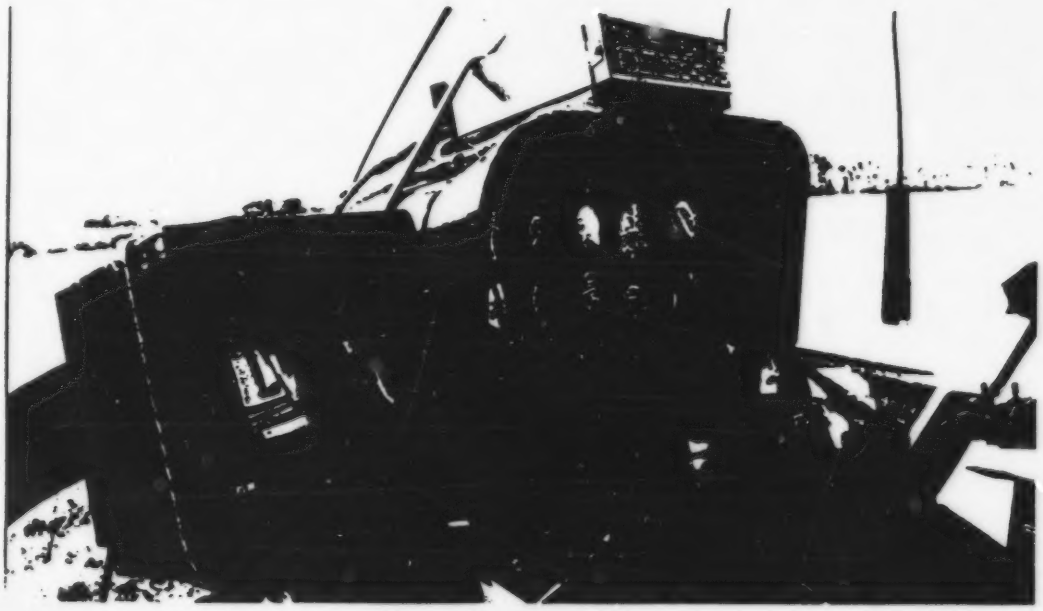

Photo 2: FLIR image screen monitor and recording unit.

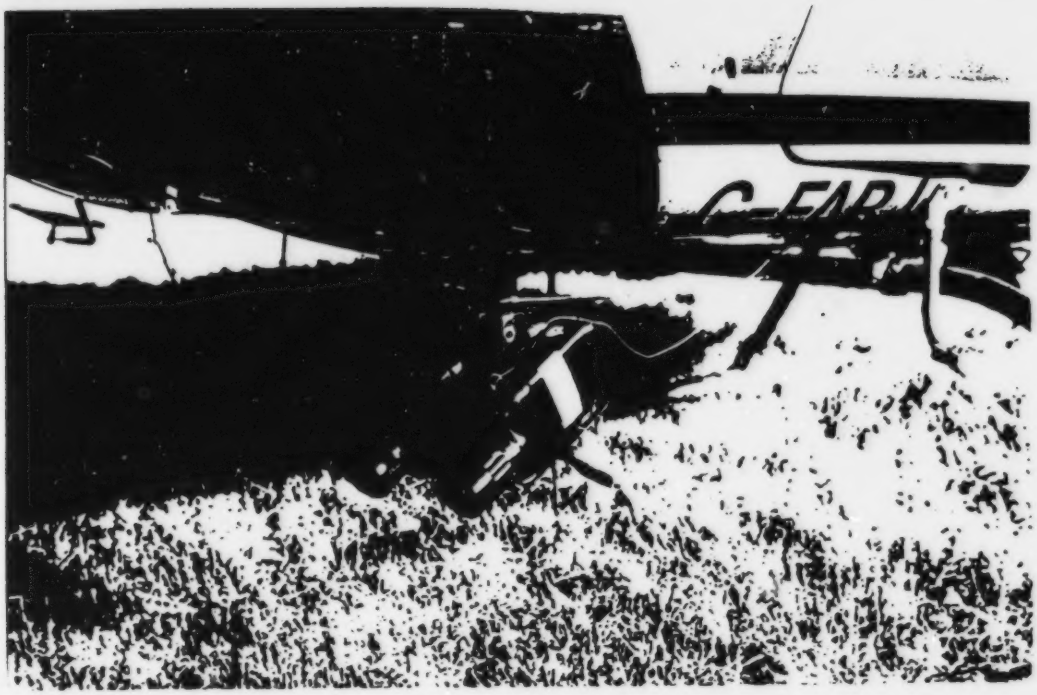

Photo 3: AGA infrared camera and video camera mounted on Aerial Recon Bell 206B Jet Ranger.

Photo 4: AGA image screen monitor and control unit.

3.0 THE TESTS

The tests were conducted October 19, 1989 on agricultural land approximately 10km east of Sundre, Alberta. To simulate the release of warm oil onto the ground, 24oC water was supplied via a water truck.

Two test sites were used:
- -Site A, 1.5m X 1.5m, had a release of 0.5 bbl water.
- -Site B, 4.5m X 6.0m, had a release of 9.0 bbl water.

To provide effective separation on the imagery screens, the two sites were separated by 25 m in a straight line flight path. (Photo 5).

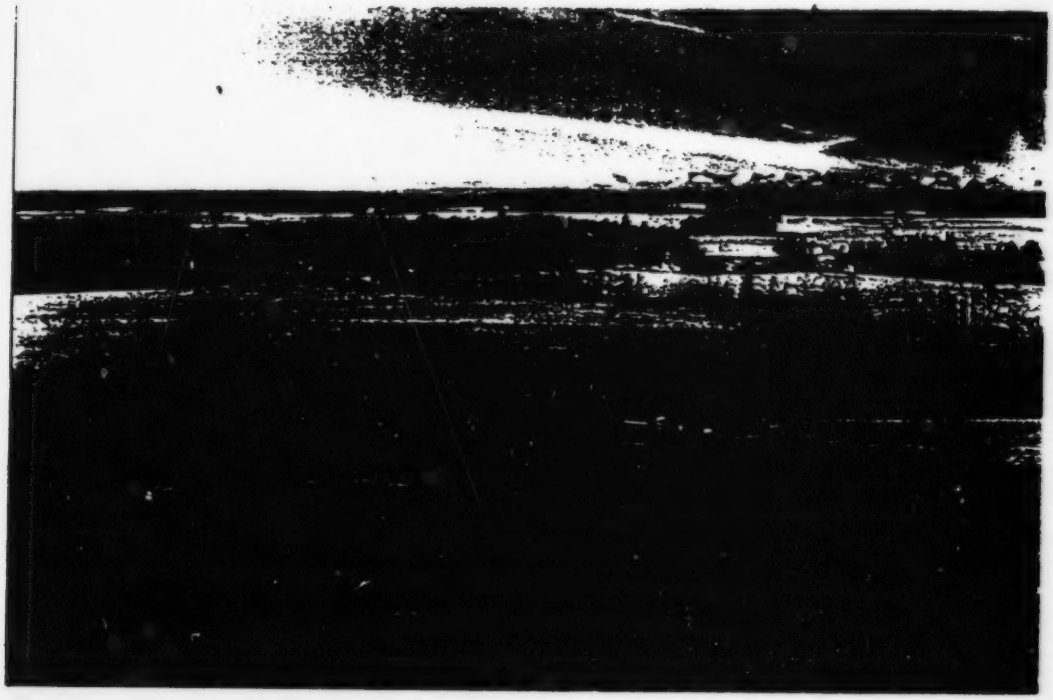

Photo 5: Location of Sites A, B, and water truck. Dashed arrows represent flight path direction.

Test Procedure:
- -Water was released at both sites at 09:47.
- -Initial ground and water temperatures (at the hose discharge point) were recorded.
- -As the water cooled over the next 100 minutes, five separate over-flights or "runs" were made by both the Aerial Recon "AGA" system and the Turbowest Helicopters "FLIR" system.
- -For each run and at each site, temperatures were recorded for:

-the ground,
-the water at the hose discharge point (Run 1 only),
-the water in surrounding puddles and/or
-the wet ground.

-A sixth run, using an aerial water spray, was to simulate a high pressure pipeline release.

-Videotapes were made from each system's infrared imagery of the runs. Photographic reproductions were then made from the videotapes. However, the non-availability of commercial equipment which can effectively reproduce photographic images from an infrared image videotape has restricted the inclusion of image samples in this report.

The variations of temperatures with time and for each run are presented in Table 1 with reference to the corresponding infrared imagery photograph. The imagery photographs in this report are at least third generation images and have therefore lost some clarity in the transformation from the on-board VCR system to the photographic print to the colour paper reproduction. The brightness of the AGA's image screen made it difficult to reproduce a quality photo from the videotape.

During the initial passes over the simulated spills, the infrared detectors clearly showed the "hot spots". As the temperature difference between the warm puddle of water and the cold ground narrowed, the hot spot became less and less apparent. Within 90 minutes, it was very difficult to detect the small spills hot spot on the video screen. By this time the temperature difference was about 5 oC.

To achieve the 0.2 oC detectable difference advertised by the equipment suppliers, both ideal conditions and highly experienced operators are required.

Photo 6: Initial water release at Site B.

Photo 7: AGA infrared survey approaching Site A.

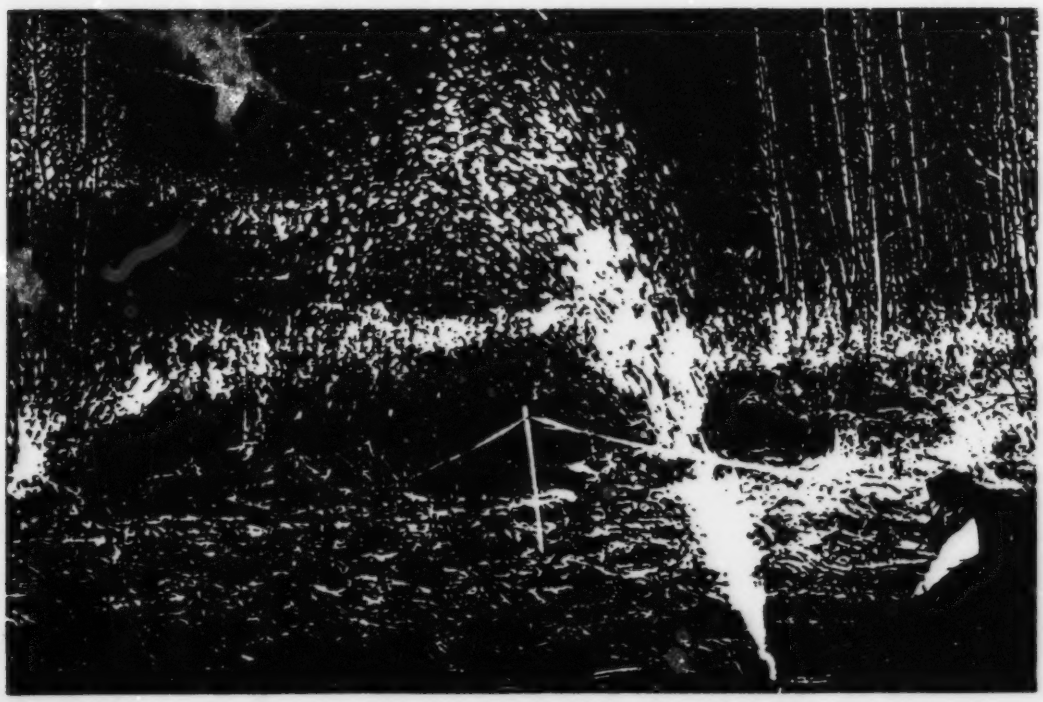

Photo 8: Run 6 water spray release at Site B.

TABLE 1

Infrared Tests: Water and Ground Temperatures

		SITE A			SITE B			
	Time	Ground TempoC	Water TempoC	Puddle TempoC	Ground TempoC	Water TempoC	Puddle TempoC	Photo #
Water Release	0947	0	24		0	24		
RUN 1								
Aerial-AGA	0950	2	24	21	0	24	22	
Turbo-FLIR	0955	2	24	21	0	24	23	10
	1000	3	24	18	0	24	20	11
RUN 2								
Aerial-AGA	1017	3	*	17	0	*	18	14
Turbo-FLIR	1019	3	*	17	0	*	18	12,13
RUN 3								
Aerial-AGA	1023	3	*	16	0	*	17	
Turbo-FLIR	1025	3	*	16	0	*	17	15
			Wet Ground TempoC			Wet Ground TempoC		
	1043	5	15.5	**	0	10	14	
RUN 4								
Aerial-AGA	1051	7	12	**	0	10	14	
Turbo-FLIR	1052	7	13.5	**	0	11.5	14	
RUN 5								
Aerial-AGA	1124	11.6	13.0	**	3	8	10	
Turbo-FLIR	1126	11.6	13.0	**	3	8	10	16
RUN 6								
Aerial-AGA	1136	24oC Water spray at Site A.						
Turbo-FLIR	1137	"	"	"				8,9 17,18

* - No "free" water remaining at point of discharge.

** - No "free" water remaining at test site.

Photo 9: Run #6 overflight at Site B.

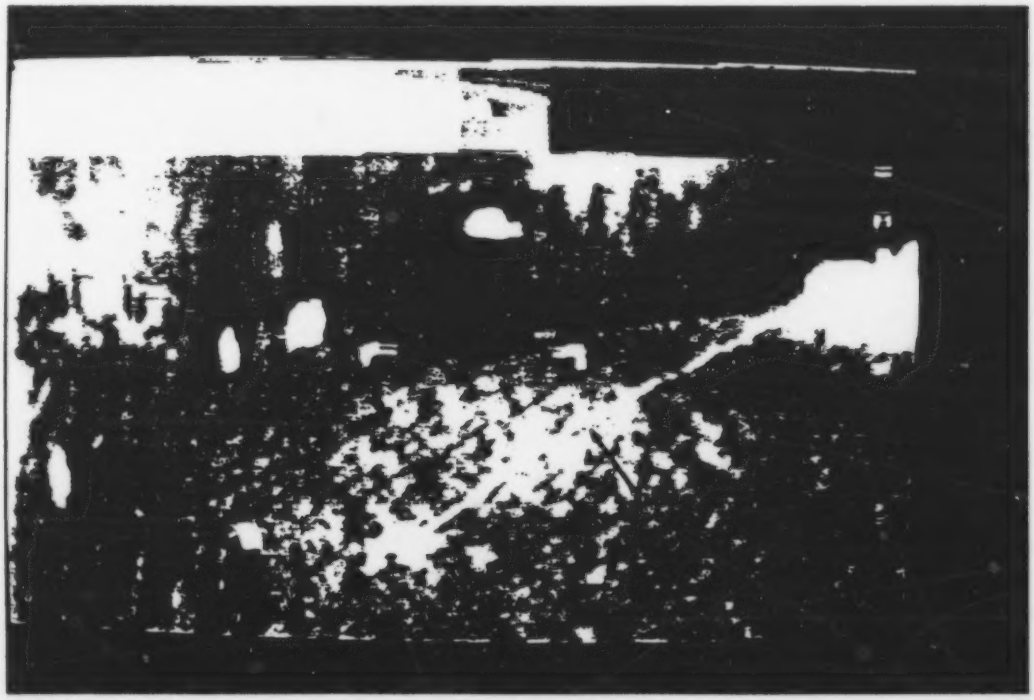

Photo 10: FLIR Infrared Run #1 showing Sites A & B.

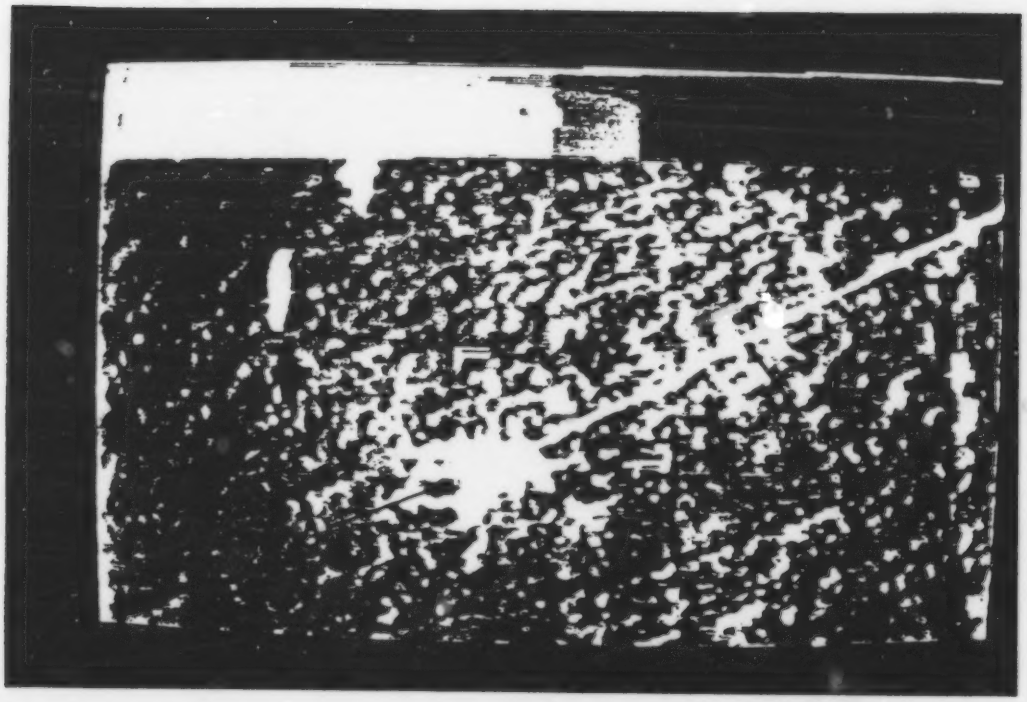

Photo 11: FLIR Infrared Run #1 showing Site A.

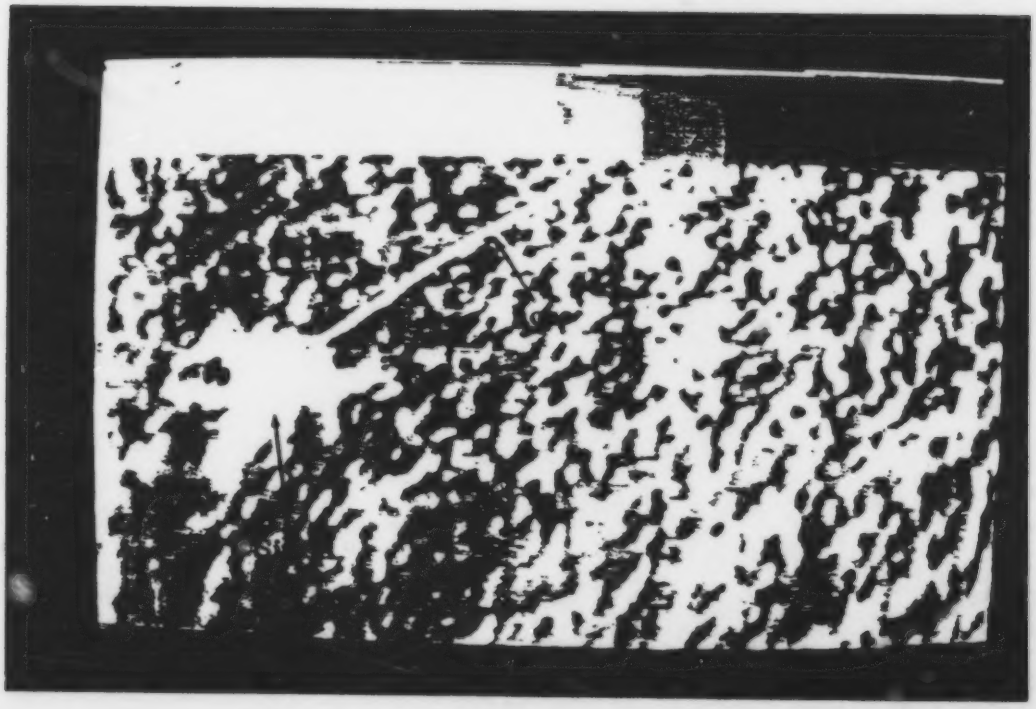

Photo 12: FLIR Infrared Run #2 showing Site A.

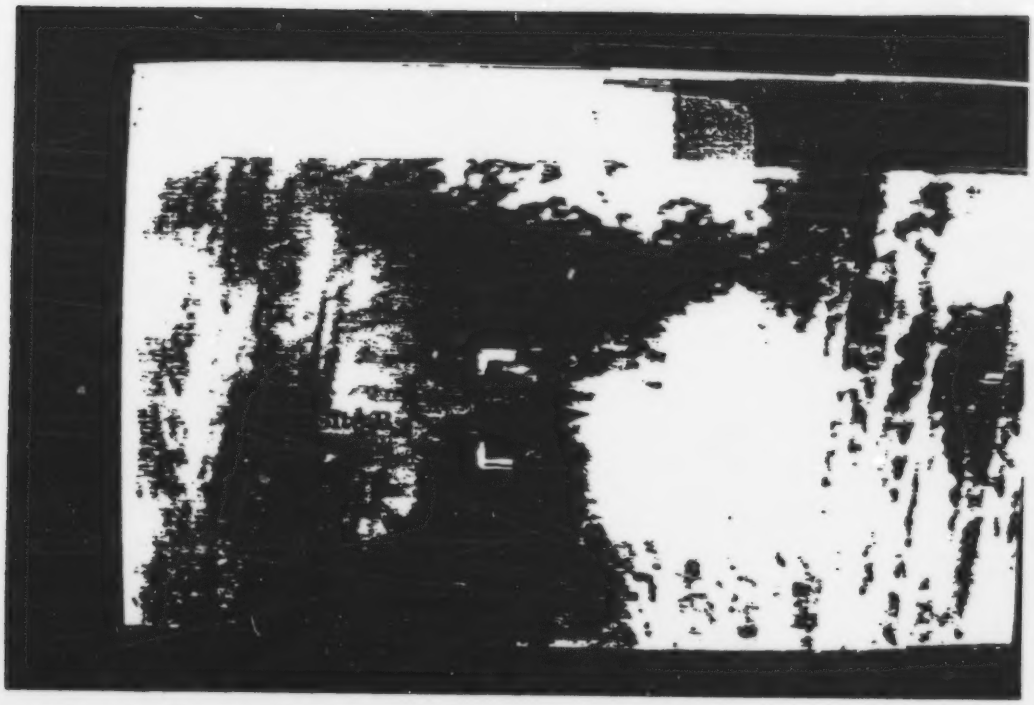

Photo 13: FLIR Infrared Run #1 showing Site B.

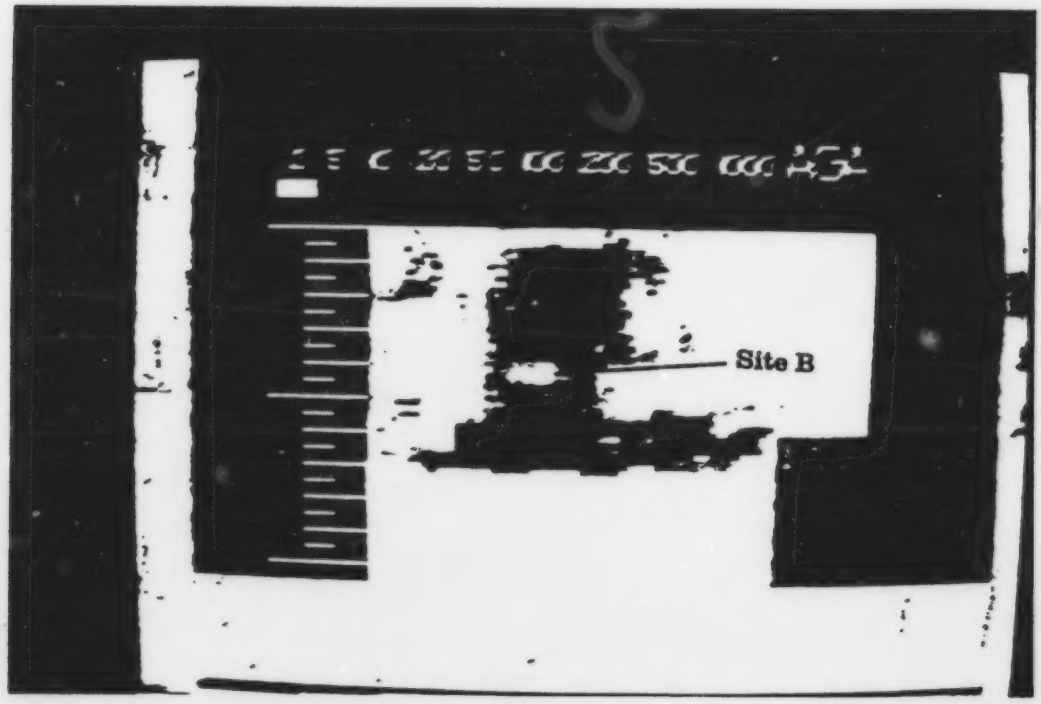

Photo 14: AGA Infrared Run #2 showing Site B.

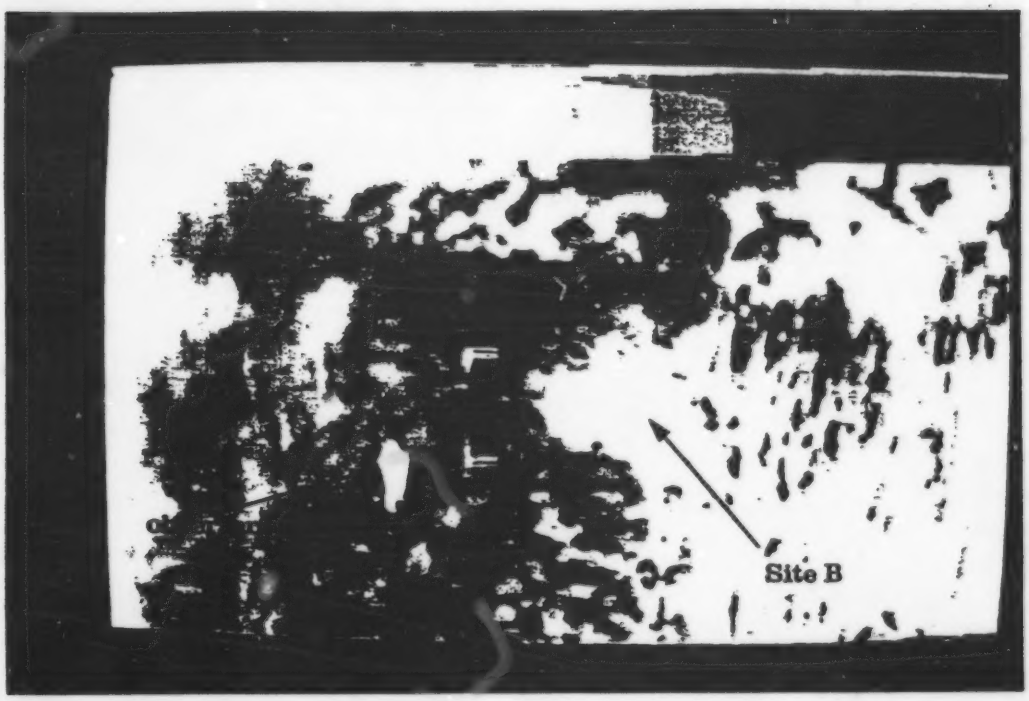

Photo 15: FLIR Infrared Run #3 showing Site B.

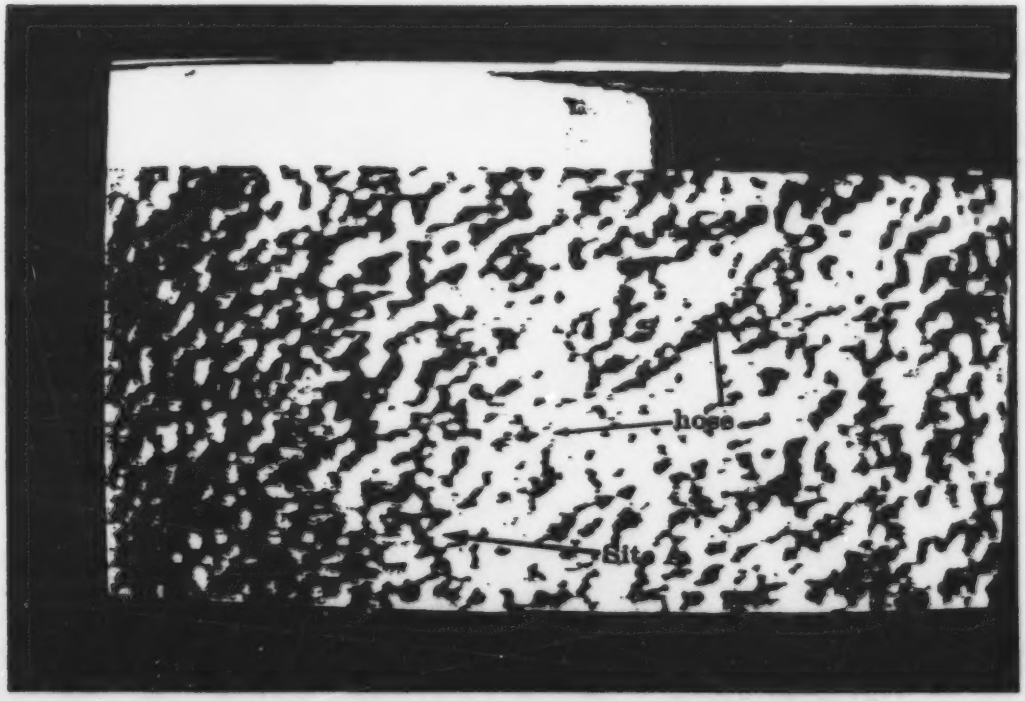

Photo 16: FLIR Infrared Run #5 showing Site A.

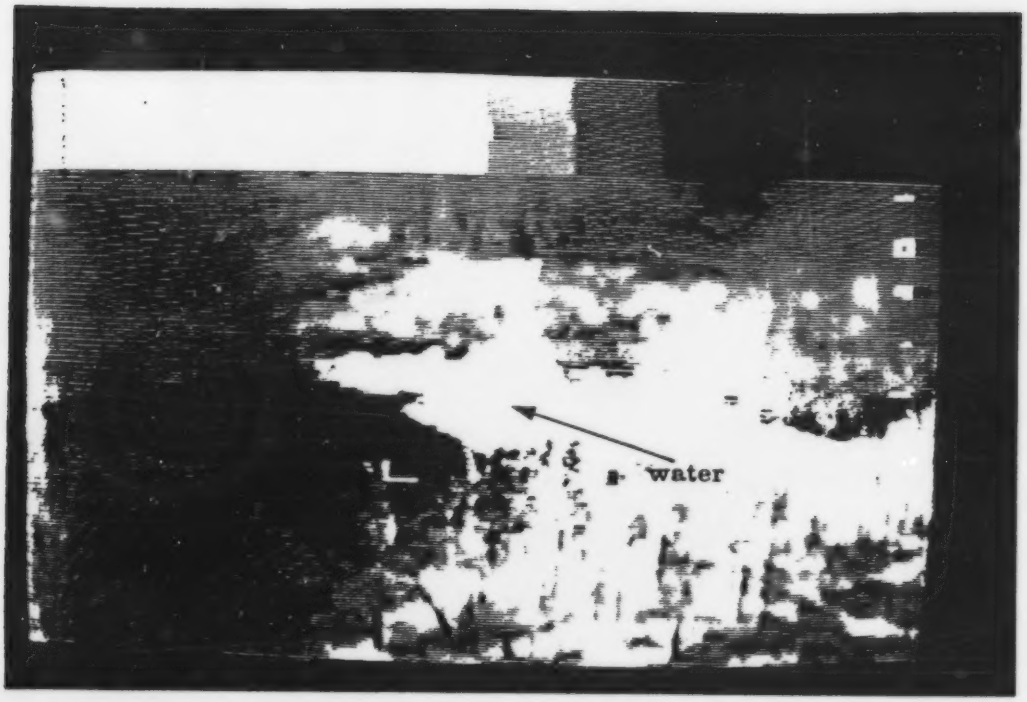

Photo 17: FLIR Infrared; approaching water spray.

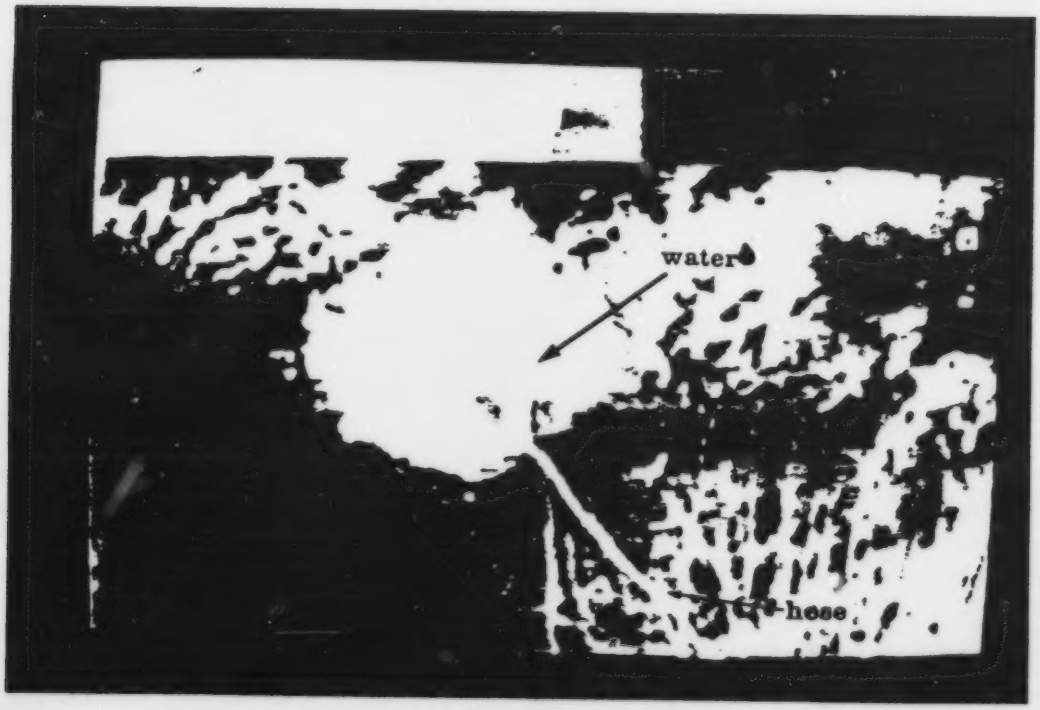

Photo 18: FLIR Infrared; above water spray.

4.0 OBSERVATIONS and CONCLUSIONS

-Both the AGA and FLIR infrared heat sensing units were successful in distinguishing the warm water spilled on the ground surface.

-Airborne thermographic detection systems are capable of finding leaks that other techniques can miss. It is also faster and potentially less expensive than any of today's alternatives. Ref 5.

-The clarity of the water's image decreased as the temperatures of the water and the ground approached equilibrium. (The ground temperature increased with the rising sun's solar radiation and the water temperature decreased due to the cold ground.) Infrared detection is directly dependent on the temperature difference between the fluid released and the ground. These temperatures are dependent on the time elapsed since a liquid leak occurred and/or the continuance of the leak.

-The helicopter's high level of mobility makes it ideal for scanning pipeline rights of ways. The option to make several low speed passes or landing for confirmation of a suspected site makes it desirable over fixed wing aircraft.

-The helicopter's infrared scanning speed of 80 to 100 kph gives a cost effective means for detecting pipeline leaks (Appendix 1).

-The AGA and FLIR infrared detection systems have proven capable in locating pipeline leaks. The aerial systems make it feasible to quickly scan pipelines and flowlines that are inaccessible due to terrain, groundcover,or remoteness and are superior to other aerial visual methods.

-The quality of the imagery that an infrared system provides is directly influenzed by the experience and qualifications of the infrared operator.

-Pilots and infrared operators must be fully briefed by the pipeline operator on the expectations of the flights.

-In the tests, some key sections of the imagery were not properly recorded. This is directly attributed to the operator's mechanical errors or the operator not understanding the intention of the flights.

-The AGA's split screen overlapping images can be very confusing to interpret. Although screens with the video image at the top of the screen was the easiest to read; perhaps two monitors or a spilt screen showing identical images in infrared and normal video would be more beneficial.

-IFR leak detection surveys should be conducted when the background ground temperature is the lowest. This provides the optimum clarity of the image (ie: early morning surveys).

-The infrared video image must be interpreted by a trained operator.

5.0 REFERENCES

1. New Development's to Complement FLIR's Image. Rotor and Wing International, September 1988, p38.

2. Forest Fire Detection and Mop-Up of Smouldering Fires: The Role of Thermography in the Alberta Forest Service. Robert Young, Fire Management Programs, Alberta Forest Service, Energy and Natural Resources. 1985.

3. FLIR in Law Enforcement: "Gotcha" in the Dark. Rotor and Wing International, August 1988, p26.

4. Innovation in Thermal Imaging. FLIR Systems Information Brochure.

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6. Thermal / Video Detection System. Aerial Recon Surveys information sheet.

Appendix 1 Infrared Scanning Costs

The costs involved with operating an infrared scanning operation contribute to the feasibility of conducting the project. The helicopter companies' field estimates range from $15.00 to $35.00 per mile of line scanned. (The actual unit capital cost for the FLIR unit is $120,000 and the AGA unit $50,000.)

Summary of an IFR Flight by Mobil Drayton Valley in May 1989

-70 lineal miles of ROW were scanned covering 4 townships.
-A Bell 206 helicopter (AGA unit) was used at an hourly rate of $700.00.
-With a scanning time of 2.5 hours, the cost was $25.00 per mile scanned (does not include ferry time).
-If the ferry time of 1.3 hours at $575.00/hour was included, the cost per mile scanned was $35.00.